Project ID # VAN028

Electric Vehicle – Grid Benefits Analysis

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Lawrence Berkeley National Laboratory

2018 DOE VTO Annual Merit Review

June 21, 2018

Overview

Timeline

- Start date: October 2017
- End date: September 2019
- Percent complete: 30%
- **First time project is reviewed separately**

Barriers

- Consumer reluctance to purchase new technologies
- Grid impacts of electric vehicles are highly uncertain
- Relating component-level technologies to national-level benefits

Budget

- Total project funding: $500K
  - DOE share: 100%
- FY 2016: Zero
- FY 2017: $97K

Partners

- Project Lead: LBNL
- Partners: ANL, UC Davis

Objectives

Relevance

- Estimate the costs and benefits of integrating millions of plug-in electric vehicles into the power system
  - Impact on the grid operating cost
  - Impact on power system generators including the curtailment of intermittent renewable energy
- By accounting for charging behavior and constrained infrastructure using the BEAM model
- The grid is simulated as it is dispatched, using the PLEXOS model, which minimizes cost in serving load reliably

California results are complete and national analysis on schedule

Date	Milestone	Status
December 2017	Discussion with VTO on progress in California-based vehicle-grid integration analysis and proposed approach for translation to national-level	Completed
March 2018	Presentation on California results and completed methodology in translating vehicle-grid integration analysis to national estimations	Completed
June 2018	Preliminary national results	On schedule
September 2018	Report/submitted journal article on PEV benefits and costs from grid integration at national level	On schedule

Key Results

Summary

- Overnight time-of-use (TOU) rate responsive charging and smart charging lower grid operating costs by up to 42% and 51% relative to unmanaged charging
- Savings per vehicle range from $60 to $150 per year
- Smart charging lowers curtailment by up to 50% while TOU actually increases curtailment
- Both smart charging and overnight TOU can defer investment costs in generation as PEV volumes increase

Method: Linked Mobility and Grid Models

Approach

Vehicle and Mobility Data:
- Road network
- Mobility (traveler activity chains)
- 2016 Vehicle Registrations
- Vehicle energy consumption and charging characteristics
- Charging infrastructure

2014 LTPP database from CAISO:
- Generator Data
- Renewable Portfolio Standard
- Non-EV Loads
- Fuel and CO_2 Prices
- Import/Export Limits
- Reserves

Grid and PEV Scenarios:
Base case: No PEVs
Under 4 adoption levels (0.95M, 2.1M, 2.5M, 5M)
- Unmanaged PEVs
- Smart charging PEVs
- Time-of-use rate PEVs

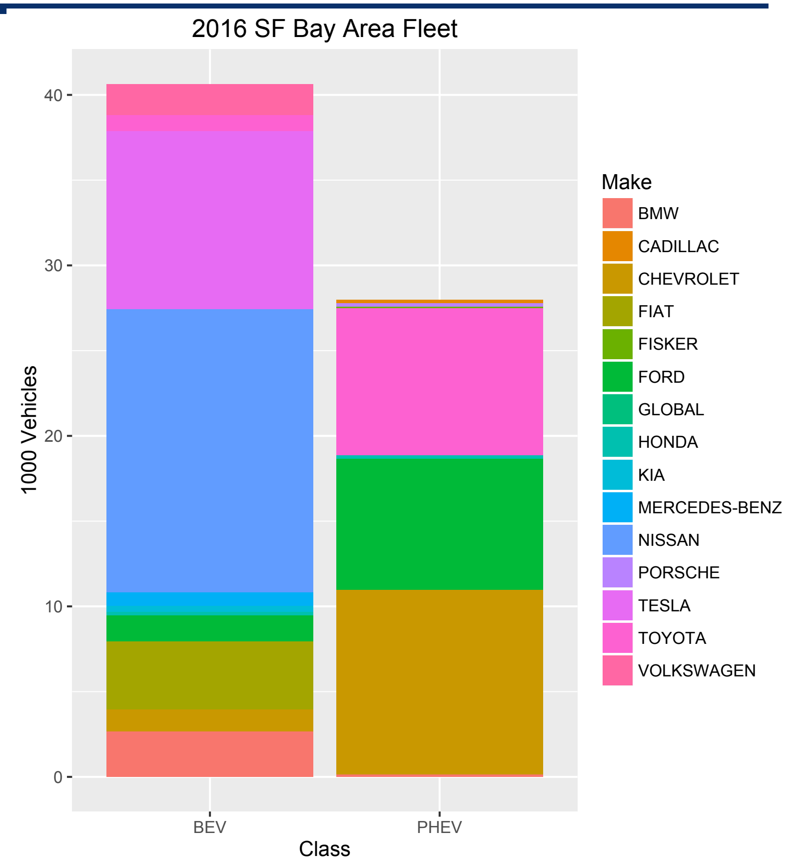
Added workplace chargers (sensitivity analysis)

1. BEAM Model: PEV Mobility/ Charging → Individual Vehicle Charging Sessions → **2. Charging Load, Scaling and Flexibility** → Aggregate 2025 CA Charging Loads and Constraints → **3. PLEXOS:** Power Sector Model → **Grid Outcomes:**
- System Operating Cost
- Renewable Curtailment

BEAM Inputs for SF Bay Area

Progress

- 2016 vehicle make & model by zip code (source: Polk IHS data)
- All PEV battery capacities increased by 50% to reflect 2025 scenario
- 60% BEVs, 40% PHEVs
- Charging infrastructure by charger type and location
- Annual eVMT by PEV type



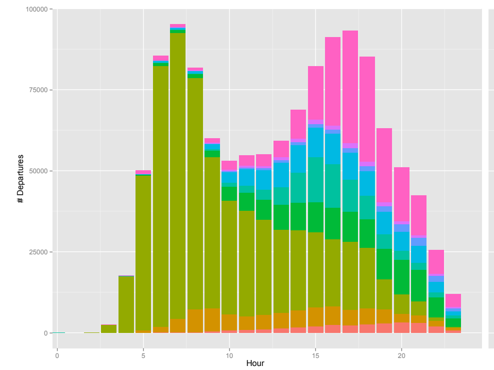
BEV and PHEV annual eVMT

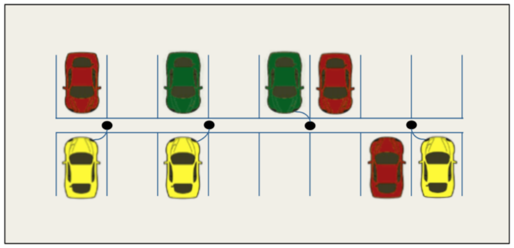
Vehicle Type	eVMT
BEVs	11,000
PHEVs	7,600

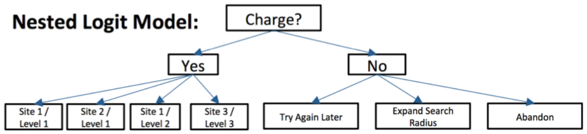
BEAM: PEV Trips and Charging Behavior

Progress

- Activity chains from MPO travel demand model
- Range-aware heuristic used to assign BEVs/PHEVs to population
- Congestion data from UCB analysis
- Unimodal runs, only PEVs are simulated
- Charging behavior is a nested logit model that is calibrated with observed ChargePoint data



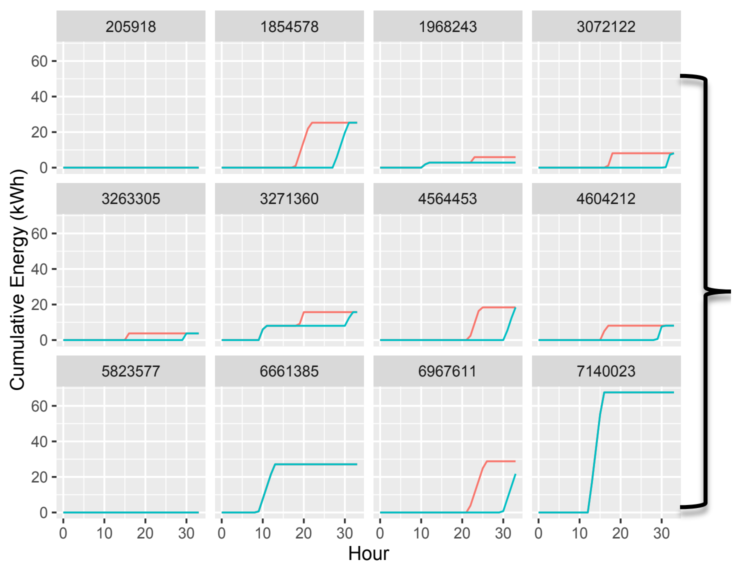




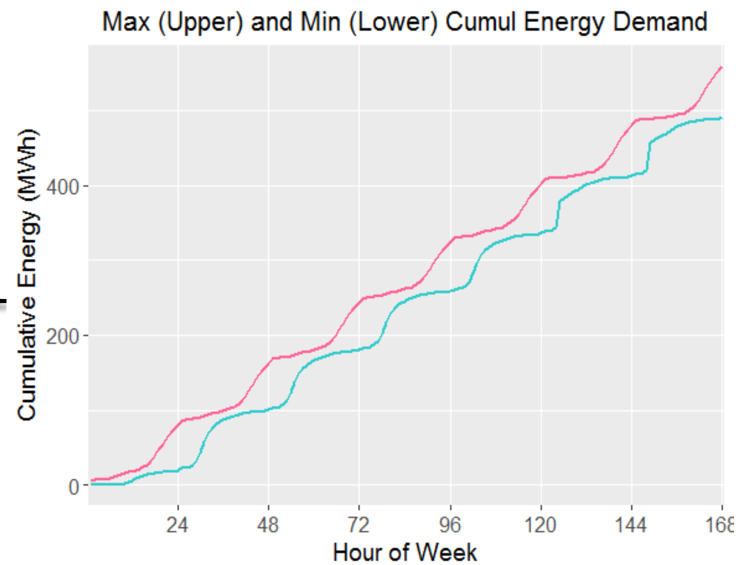
Charging Strategies Modeled

Progress

- BEAM first simulates **unmanaged** and **TOU** charging → produces fixed load profiles for Bay Area drivers
- BEAM generates **smart** charging constraints for individual drivers → Vertical summation to aggregate upper and lower limits
  - Same energy delivered as unmanaged charging session



Individual Session Constraints



Aggregated Constraints

Aggregated PEV Charging for CA in 2025

Progress

- Aggregated loads and constraints represent charging flexibility potential for 2016 SF Bay Area
- For each charging strategy:
  - We scale these separately for BEVs (60%) and PHEVs (40%) to reach statewide CEC forecast of 2025 PEV penetration for each CA utility

Scenarios of 2025 California PEV adoption simulated under each charging strategy

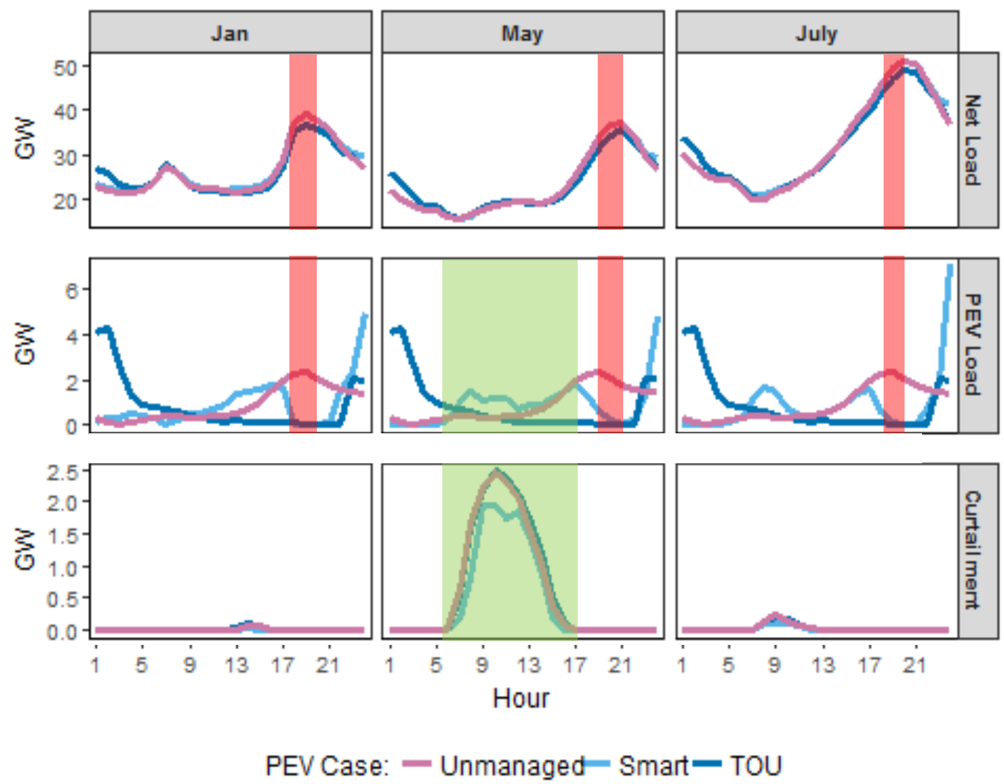
	Low	Mid	High	"Reach"
Total PEV Charging Load (GWh)	3,016	6,668	7,938	15,876
Total Stock of PEVs	950,000	2,100,000	2,500,000	5,000,000
PEVs % of Current CA Auto Stock	4%	8%	10%	20%

Results: PEV Charging Load

Accomplishment

- Unmanaged charging coincides with peak load and ramp on grid (red); smart and TOU charging alleviates peak
- Smart charging increases during times of renewable curtailment (green), especially in spring

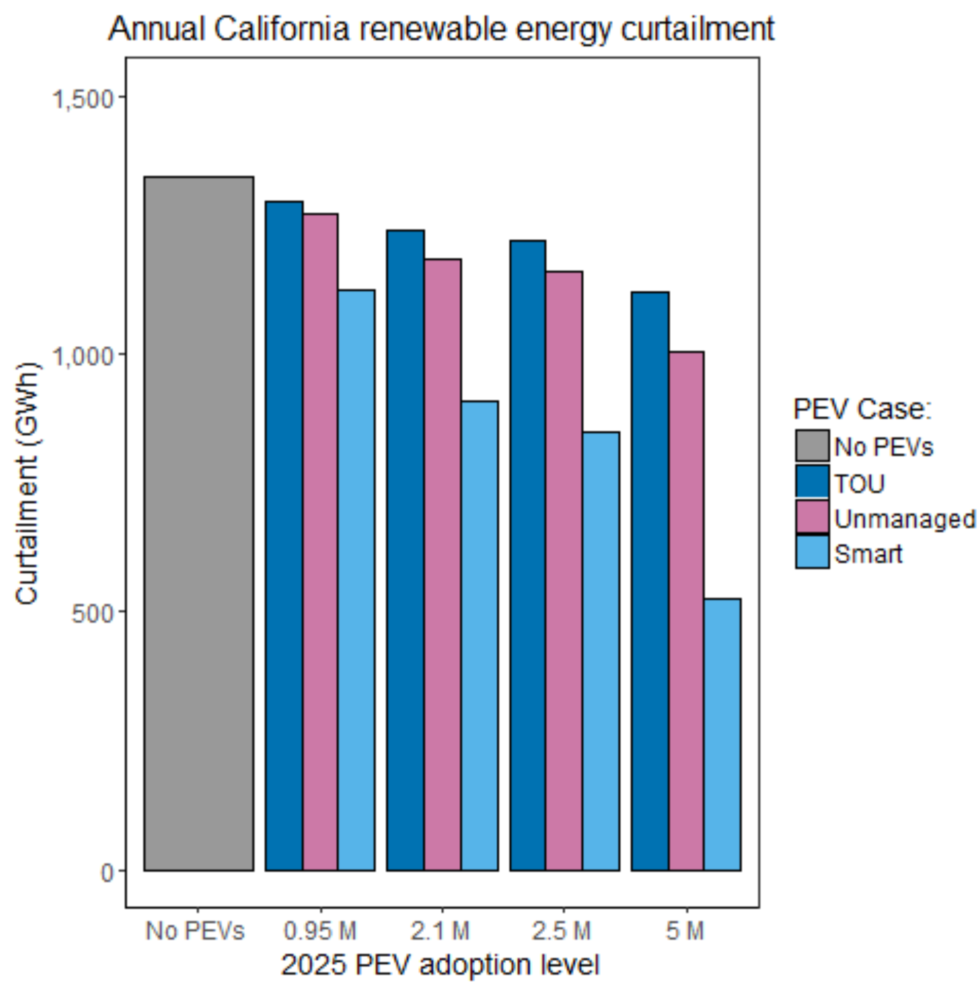
CA Load, charging patterns and RE curtailment



RE curtailment reduced by smart charging

Accomplishment

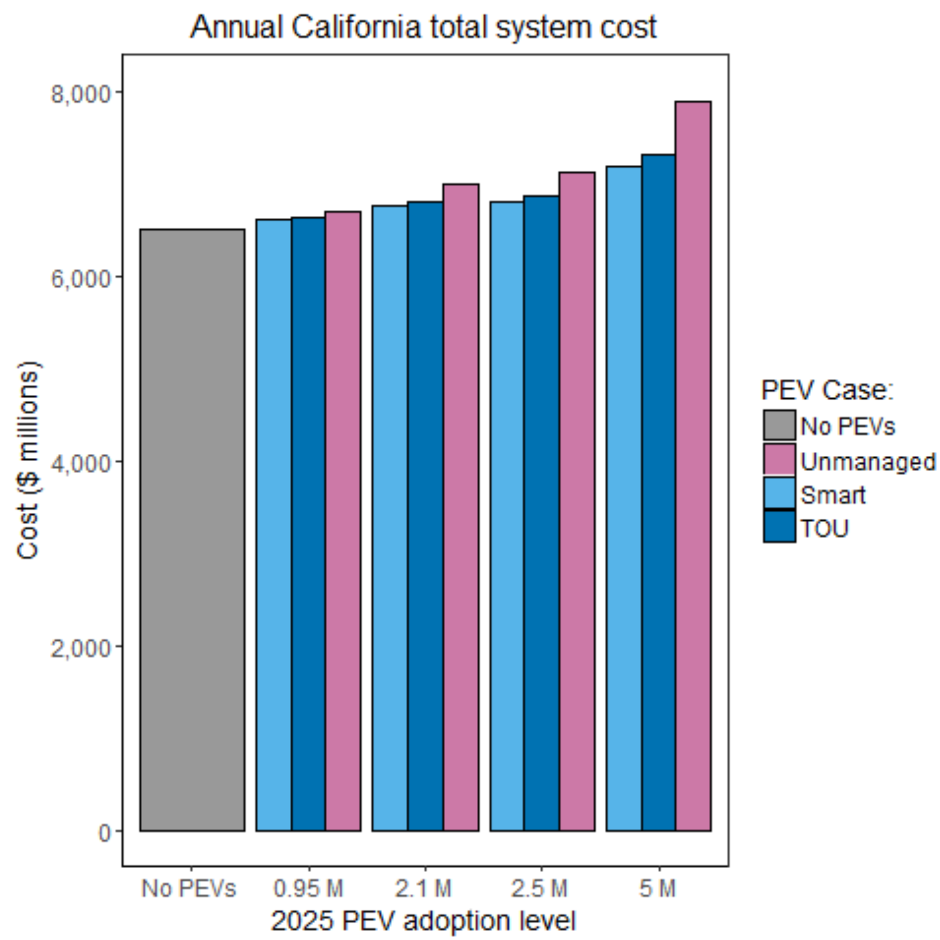
- Curtailment: Generators turned down from full capacity usually due to over-supply
- Renewable curtailment reduced up to 48% with 5M smart charging vehicles
- Curtailment minimally reduced with unmanaged charging, worsened with time-of-use



Managed charging saves grid operating costs

Accomplishment

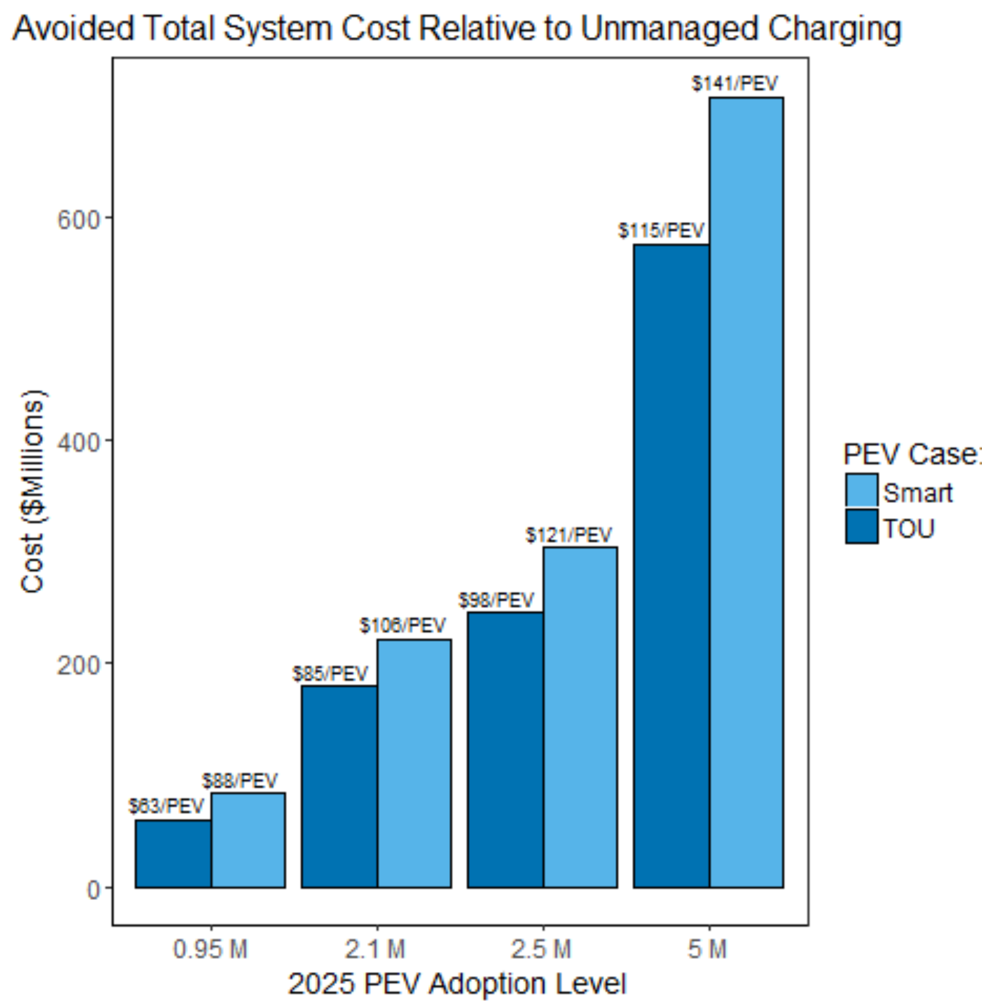
- Most of cost savings from smart charging can be achieved with overnight TOU charging
- Smart and TOU charging can defer expensive capacity expansion, while unmanaged charging exacerbates peak



Managed charging saves grid operating costs

Accomplishment

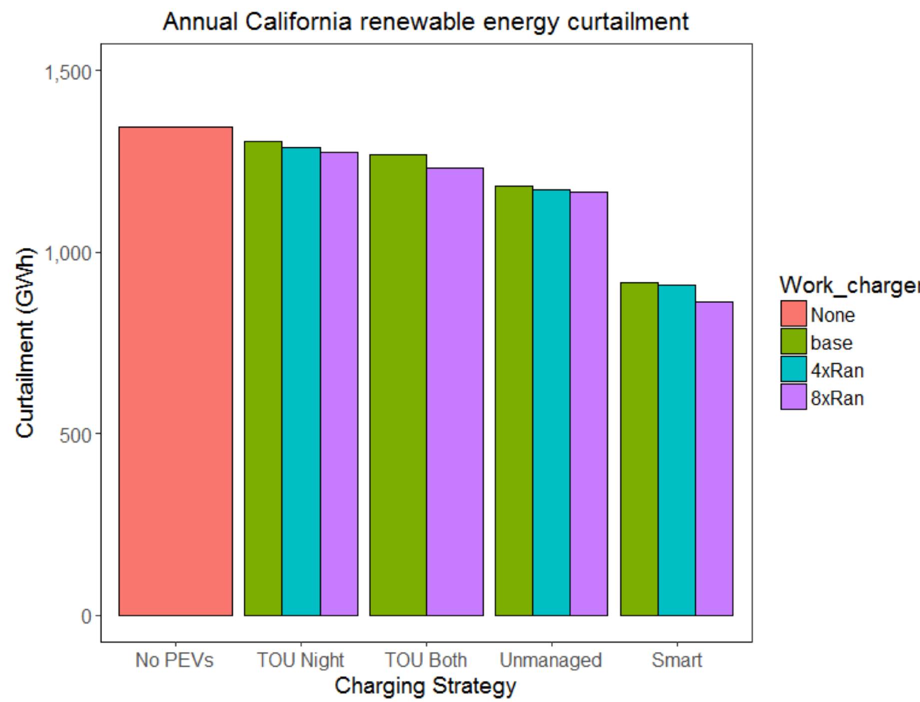
- With 2.5M PEVs, ~$300M of annual grid operating cost savings when PEVs participate in smart charging vs. left unmanaged
- But annual average per vehicle savings is low with both smart and TOU charging



Increased workplace charging infrastructure

Accomplishment

- Follow-up study to analyze grid impact of adding 4x and 8x more workplace charging infrastructure, and daytime TOU charging



Response to FY17 Reviewer Comments

- This is the first time this project is being reviewed independently. The work under this project was reviewed as part of the overall Benefits Analysis led by ANL

Collaborations

- The results of this work at the national level will feed into the VTO Program Benefits Analysis project led by ANL
- Working with UC Davis to scale up grid modeling to national scale

Remaining Challenges and Barriers

- Scaling up California result to national-level requires a simplified representation of charging behavior and infrastructure constraints
- We have developed a reduced form model for the mobility side

- National grid dispatch modeling using PLEXOS is computationally very intensive
- We are working with UC Davis, who have developed a reduced form national grid dispatch model

Proposed Future Work

- If future mobility relies heavily on automated ridehailing fleets, how will PEV charging demand load change?
- What will be the economic impact on the grid?
- Can AV-ridehailing fleets accelerate the integration of renewable energy on the grid

Any proposed future work is subject to change based on funding levels

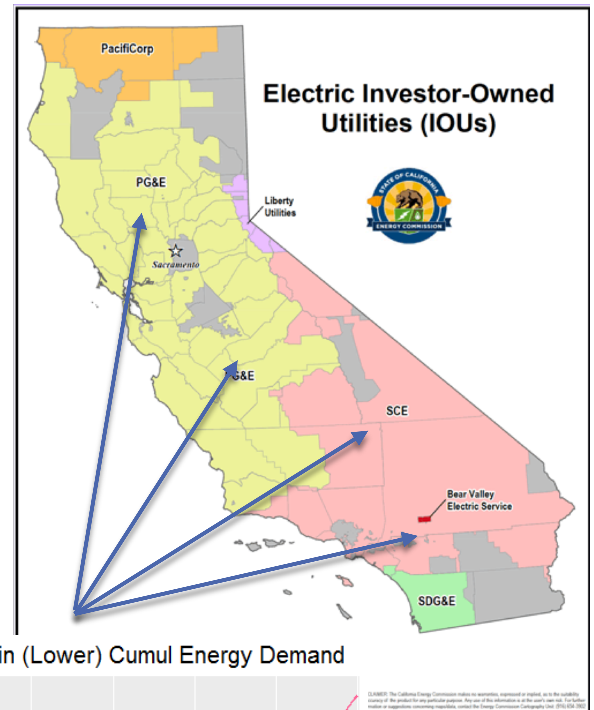
Summary

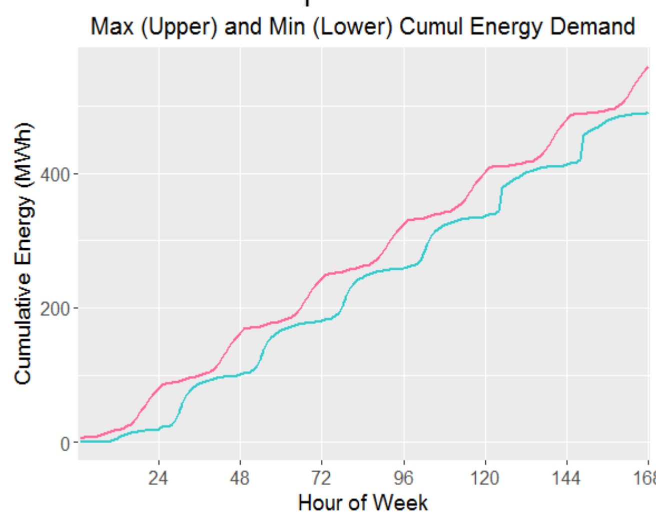
- California analysis shows that PEVs can be very beneficial in increasing the utilization of renewable energy at higher penetrations
- Smart charging can lower operating costs for the grid but the benefits at a per vehicle level are not substantial
- We are implementing the methodology to estimate the national level grid impacts of privately owned PEVs at high levels of penetration
- We are collaborating with both ANL and UC Davis

TECHNICAL BACKUP SLIDES

Aggregated PEV Loads and Constraints Added to Grid Model

- Western US grid modeled with PLEXOS optimization model
- 50% Renewable Energy modeled for CA grid
  - Non-PEV loads, generator costs, transmission constraints, and other grid data from CAISO database used for statewide grid planning
- Aggregated PEV loads to PLEXOS for each CA utility





Detailed Charging and Grid Metrics